A Goddard Latent Heating Algorithm for GPM: Tropical and Extra-tropical Retrievals

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CSH Algorithm Development

Original - Tao *et al.* (1993): 2 pairs of surface rainfall-normalized heating (Q1) profiles (land/ocean, convective/stratiform) from sounding arrays and a few GCE simulations, for TRMM, 1 pair for shallow (i.e., echo tops < 5 km) added later

Updated - Tao *et al.* (2010): look-up tables (LUTs) with 36 surface rain intensity and 20 stratiform bins based on several multi-week 2D Goddard Cumulus Ensemble model (GCE) simulations, separate heating components (i.e., LH, eddy, and Qr), LUTs composited into land/ocean using conditional rain rates (differentiate narrow intense vs broad weak rain features) for rainy, near rain, and far from rain areas, w/ Q2 (moistening), for TRMM

NEXT GENERATION – 2017 (for GPM + TRMM):

Lang and Tao (2017): same basic 2010 LUT framework for Tropics/warm season but w/ new GCE simulations (4ICE vs 3ICE microphysics – better radar/rain structures), w/ additional cases (more sampling), and LUTs further differentiated by **echo top height** (5 bins, every 2 km – better heating depth) and **low-level (0-2 km) dBZ gradient** (increasing/decreasing towards sfc – less/more evaporation)

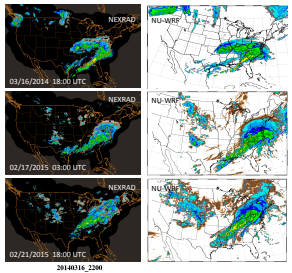
Tao et al. (2017): new cold season algorithm. **LUT (6 storm top, 13 freezing level, 6 max dBZ level, 2 dBZ gradient bins), 90 composite dBZ intensity bins, LH only,** based on 6 NU-WRF 4ICE simulations (3 Eastern US snow storms + 3 West Coast Atm. Rivers)

New GCE WARM SEASON Simulations

- 2D GCE, 70 stretched vertical levels, 512 km horizontal domain, 1 km resolution
- New Goddard 4ICE scheme (Lang *et al.* 2014; Tao *et al.* 2016) w/ improved radar structures, surface rain rates, bin-based rain evaporation correction

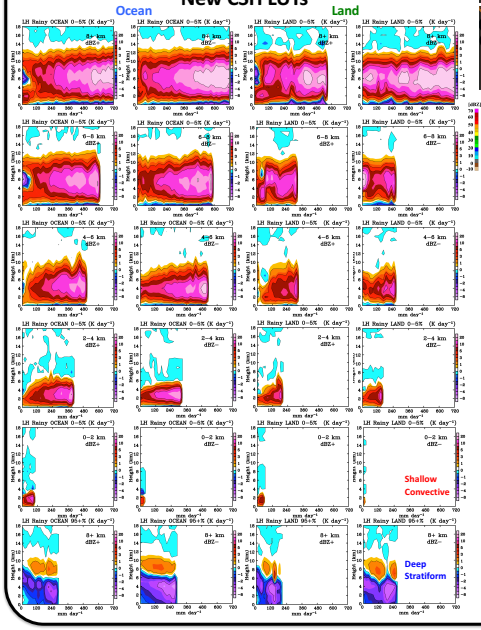
OCEAN CASES (new)	LAND CASES (new)
GATE	ARM 1997
KWAJEX	ARM 2002
SCSMEX	MC3E 2011 (33 days)
TOGA COARE	GOAMAZON 2014 (40 days)
TWPICE (20 days)	
DYNAMO (31 days)	

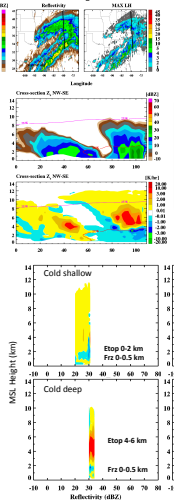
NU-WRF SYNOPTIC Simulations



3 Eastern US Synoptic Snow Events
3 West Coast Atmospheric River Events

New CSH LUTs

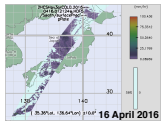


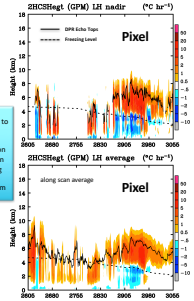


Extra-tropics Cold Season LUT

- 13 (0.5km) Freezing Levels
- 6 (2km) Echo Top Hgt Bins
- 6 (2km) Max dBZ Hgt Bins
- +/- dBZ towards Surface
- 90 (1dBZ) Composite dBZ Bins (intensity)

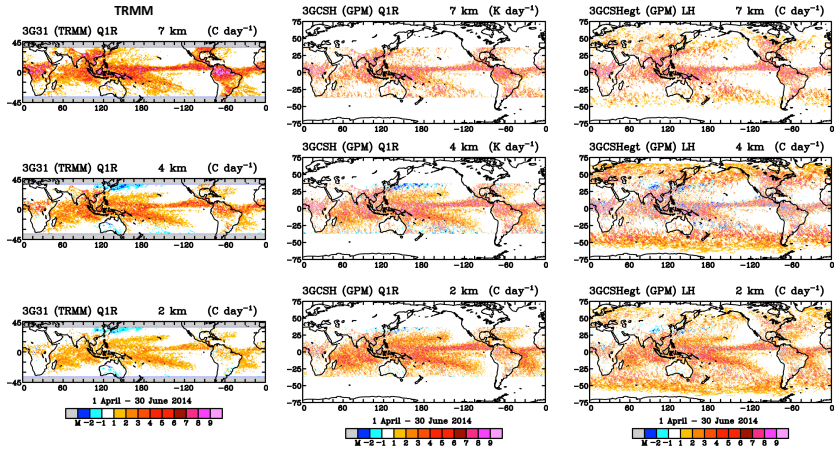
Synoptic Case



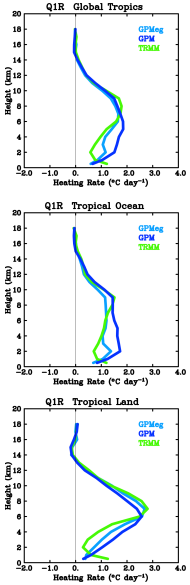


Tropical to Extra-tropical transition based on Freezing level 4 → 3 km

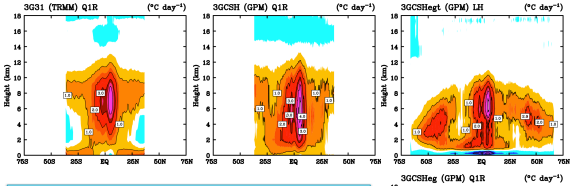
New GPM Retrievals (vs TRMM)



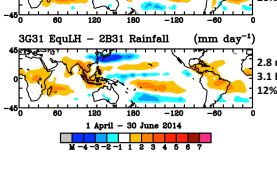
Mean Profiles



Zonal Averages



3GCSHegt (V05) incorporates echo tops heights and low-level (0-2 km) vertical reflectivity gradients in the Tropics and uses echo top heights, freezing level height, height of max dBZ, and vertical dBZ gradient in the Extra-tropics while accounting for the rain/radar coverage (composite) within each 0.25° x 0.25° grid; tropical to extra-tropical retrievals are transitioned linearly based on freezing level height from 4 → 3 km



LH vs Rain Balance

Summary and Future Work

- CSH algorithm tropical/warm season LUTs were upgraded with new GCE simulations using Goddard 4ICE microphysics and more cases
- 2 new metrics were added into the LUTs: echo top heights (for more precise heating depths) and low-level (0-2 km) vertical dBZ gradients (discern stronger/weaker low-level evaporative cooling and possibly different convective growth stages)
- TRMM and GPM retrievals are similar aloft in the deep tropics; GPM retrievals have more low-level heating due to GPM's detection of more shallow rain; however, without the new metrics, GPM retrievals have excessive mid-level heating and amplified heating biases; with the new metrics, overall heat balance is quite good
- A new cold season LUT was added based on 6 NU-WRF simulations; the LUT depends on echo tops, freezing level, max dBZ height, vertical dBZ gradient, and composite dBZ intensity; retrievals are transitioned from tropical to extra-tropical by freezing level (4 to 3 km)
- Additional GCE configurations (larger domains, 3D and quasi-3D) and finer horizontal resolutions (~200 m or less) will be evaluated

Lang, S. and W.-K. Tao, (2017): ***The Next-Generation Goddard CSH Algorithm: New Tropical and Warm Season Retrievals, J. Climate (in revision)***

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